REVIEW OF THE DEVELOPMENT OF THE ISO SIDE IMPACT TEST PROCEDURE FOR CHILD RESTRAINT SYSTEMS

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ABSTRACT

Side impacts are frequent and can pose a hazard for children travelling at the struck side in passenger cars. Although the number of seriously injured children has decreased during the last decades, there is still a considerable risk especially for head, neck and thorax injuries.
ISO/TC 22/SC12/WG 1 (working group on child safety inside passenger cars) has been working on the definition of a side impact test procedure for child restraint systems for a number of years, taking into account other side impact test procedures for CRS (child restraint system) already implemented in some countries.
This paper is a comprehensive summary of accident data (from USA and Europe), boundary conditions to be recognised for the definition of a side impact test procedure for CRS (crash worthiness, geometry, etc.) and current side impact test procedures. Special emphasis is given to the design specification for a suitable test procedure with respect to loading conditions and test severity based on full-scale test data. The paper is based on a recent ISO Technical Report, which is a comprehensive base for the future ISO test procedure development.

INTRODUCTION

ISO/TC 22/SC12/WG1 has been working on the definition of a side impact test procedure for child restraint systems. After meeting the deadline for finalisation of a third DIS (Draft International Standard) version and with disapprovals (by a small margin) of the previous two DIS votings, it was decided to finalise the current project with a Technical Report and to restart the process of developing an international standard.
The aim of this report is to summarise the work done within ISO, and to collect additional relevant information to form a solid base for the restarted project.
This paper repeats the most important parts of the Technical Report. In addition the current status of the ISO side impact test procedure for CRS standardisation is summarised.

ACCIDENT STATISTICS

The severity of injuries in side impacts depends on the seating position. It can be noticed that the severity of injuries is much higher for children sitting on the struck side than sitting on the non-struck side. The share of injuries on the non-struck side is comparable to frontal impacts, while the injury probability is much higher in struck side accidents, see Figure 1.

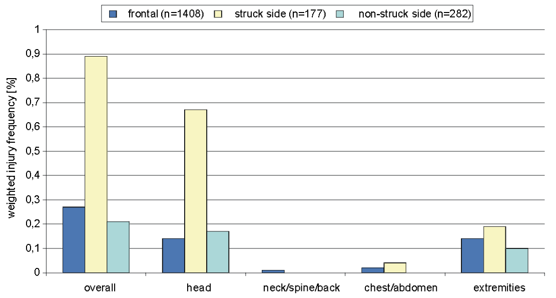


Figure 1. Injury frequency depending on the impact direction [Arbogast, 2004].

Even when analysing all lateral impact accidents the relative number of children suffering MAIS 2+ injuries is much higher than for other impact directions, see Figure 2.

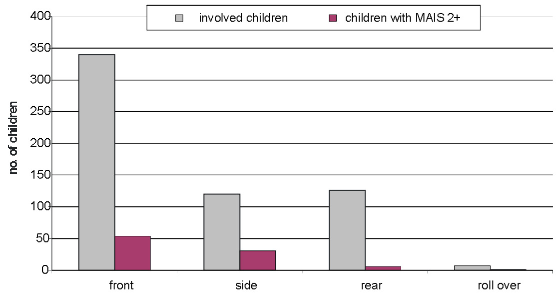


Figure 2. Share of different impact directions [Langwieder, 2002].

Regarding the different body regions the risk for severe injuries decreases from the head down to the legs. The frequently observed injuries of arms and legs are not of high severity, but may cause long term impairments. The focus for investigations concerning improvements of CRS should be on the head, neck and thorax, see Figure 3.

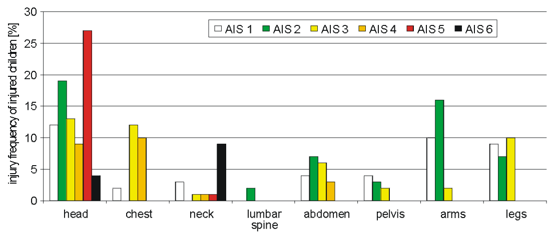


Figure 3. Injury risk of different body regions of 68 injured children in side impacts [Langwieder, 1996].

Looking at the development of injuries in lateral impacts from 1985 to 2001 in Germany it is obvious that the injury probability decreased since 1985 while the risk to suffer neck injuries increased and the chest remained unchanged, see Figures 4, 5 and 6.

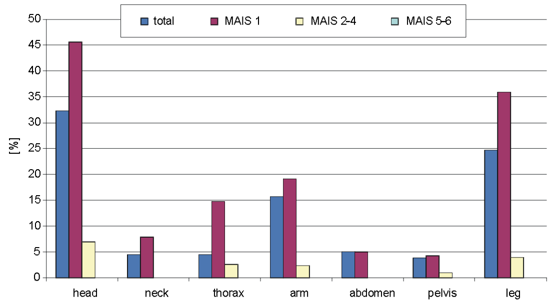


Figure 4. Injury probability of different body regions in side impact accidents between 1985 and 1990 [Otte, 2003].

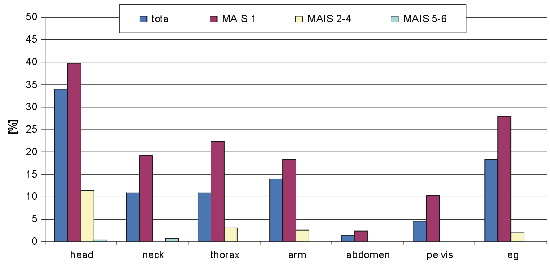


Figure 5. Injury probability of different body regions in side impact accidents between 1991 and 1996 [Otte, 2003].

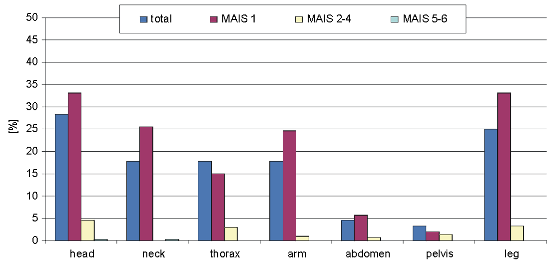


Figure 6. Injury probability of different body regions in side impact accidents between 1997 and 2001 [Otte, 2003].

The presented accident shows that side impact accidents are severe ones especially for those children sitting at the struck side. Especially head, neck and chest need to be protected.

In a study of the Swedish accident situation Jakobsson et al. [Jakobsson, 2005] did not find any moderate-severe (AIS2+) head injuries in children using rear-facing (RF) CRS involved in lateral impact accidents, while children using forward facing (FF) booster seats or the car belt only suffered from moderate-severe injuries (AIS2+) in side impacts. Comparing the injury risk for RF and FF CRS in frontal and lateral impact accidents of NASS Data (US American accident data base) of the years 1988 to 2003 Crandall et al. [Crandall, 2005] observed a ratio of 4.32 in favour of RF seats. The ratio was felt to be larger than expected.

SIDE IMPACT TEST METHODS FOR CARS

The full-scale test methods have been validated against the real world accident conditions in the specific regions. We can therefore utilise these test methods in the development of the child side impact test procedure.

European Side Impact Test Methods

In Europe the compulsory side impact test method is described in ECE R95. In addition Euro-NCAP defined a side impact test procedure, which is similar to ECE R95.

ECE R95 - A moveable deformable barrier (MDB) strikes the test car with a velocity of 50 km/h in an angle of 90°. The barrier has a weight of 950 kg and a width of 1500 mm. The deformable element has a ground clearance of 300 mm. The centre line of the MDB should match with the X position of the hip point of the 95-percentile dummy (R-point). A Euro SID dummy is positioned in the driver's seat. No child dummies are prescribed for ECE R95.

Euro-NCAP Lateral Test - The Euro-NCAP side impact test protocol is in most parts similar to that of ECE R95. The most important differences to ECE R95 are that an ES2 dummy is used in the front driver's position and child dummies are used in the rear. The two following opportunities for the CRS installation are possible:

- P1.5 on the struck side and P3 on the non struck side;
- P1.5 on the middle rear seat and P3 on the struck side.

If a head protection system is available in the car, it can be tested in a pole test. The car travels with a velocity of 29 km/h laterally into a rigid pole with a diameter of 254 mm. No child dummies are used in this test.

US Side Impact Test Methods

The compulsory side impact test method in the US is defined in FMVSS 214 and 201. In addition consumer tests are defined by US-NCAP and IIHS.

FMVSS 214 - A crabbed barrier hits with a velocity of 54 km/h the stationary test car, see Figure 7. Because of the 27° angle of the barrier the velocity has a theoretical component of 48 km/h in the car Y-direction and 25 km/h in car X-direction. The X component should simulate that the struck car is moving in normal lateral accidents. The barriers face has a width of 1676 mm and a ground clearance of 279 mm. The "bumper part" of the deformable element has a ground clearance of 330 mm. The mass of the trolley is 1368 kg. US SID dummies are used at the front and rear struck side seat. No child dummies are tested according to FMVSS 214.

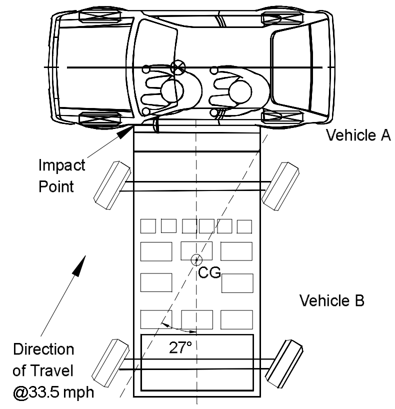


Figure 7. Impact configuration according to FMVSS 214 [NHTSA, 2003].

FMVSS 201 describes a pole test, which formed the basis for the Euro-NCAP pole test described above.

US-NCAP Lateral Test - The US-NCAP side impact test procedure is analogous to the FMVSS 214 protocol. The main difference is that the impact speed is 5 mph higher in the NCAP test compared to FMVSS 214. This means an impact velocity of 62 km/h representing 55 km/h in car Y direction and 30 km/h in X direction.

IIHS Lateral Test - The Insurance Institute for Highway Safety (IIHS) defined a more severe side impact procedure, which should represent accidents with SUV.
A trolley with a mass of 1500 kg hits the car in a purely lateral impact with a velocity of 50 km/h. The ground clearance of the barrier face is 379 mm, while the ground clearance of the bumper element is 430 mm. The shape of the barrier element shall comply with the front end shape of SUV's, see Figure 8. Two SID-II dummies are used in the front and rear seats on the vehicle's struck side. No child dummies are used in the IIHS side impact test.

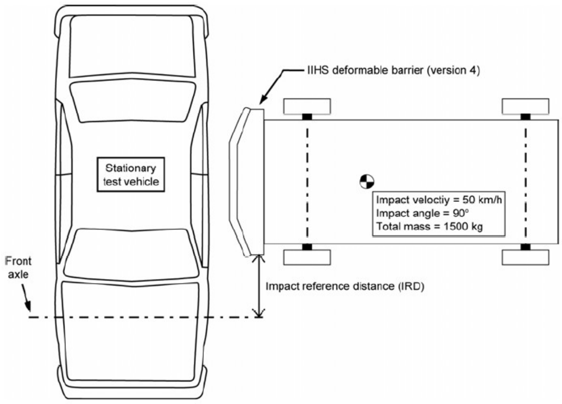


Figure 8. Test configuration in IIHS side impact test [IIHS, 2005].

Japanese Side Impact Test Method

In Japan, ECE R95 (see above) is used for compulsory side impact tests. J-NCAP utilises Euro-NCAP side impact test method (see above) with some changes. The most important within this context are:

- Test speed is 55 km/h;
- No child dummies are prescribed.

Australian Side Impact Test Method

The compulsory side impact test for cars in Australia is defined by ADR72, which is equal to ECE R95 (as described above). The Australian consumer test programme (ANCAP) follows in most parts the protocols of Euro-NCAP (see above). However, no child dummies are tested in the rear seat.

CHILD RELATED PROPERTIES OF CAR SIDE IMPACT TEST METHODS

In several full-scale crash tests according to ECE R95 performed in the last ten years, dynamic lateral intrusions of front and rear doors were measured. The sample includes super minis, family cars, executive cars and mini multi-purpose vehicles of the model years from 1990 until 2004. Both two-door and four-door cars are included. In the last tests the revised deformable barrier face according to EEVC/WG 13 was used. In all test the lateral intrusion of the inner part of the doors was measured with a string potentiometer or a cross tube positioned at the middle of the door. Intrusion velocities were calculated from the intrusion time history diagrams. For comparison, car-to-car test results are analysed too.

Door Intrusion Depth

The maximum intrusion depth of the front door varies from 180 mm to 310 mm, whereas the newer vehicles have lower intrusions (Figure 9).

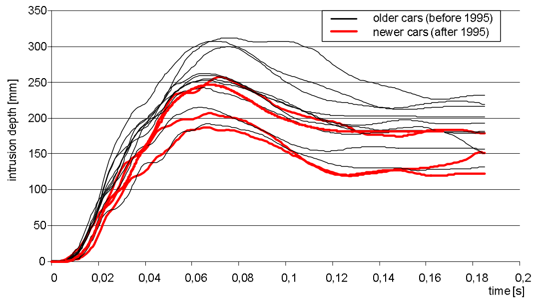


Figure 9. Front door intrusion depth in according to ECE R95 [Johannsen, 2005].

It can be seen that the maximum intrusion depth of the rear door varies from 170 mm to 280 mm, which indicates that the intrusion depth is lower at the rear door compared with the front door (Figure 10).

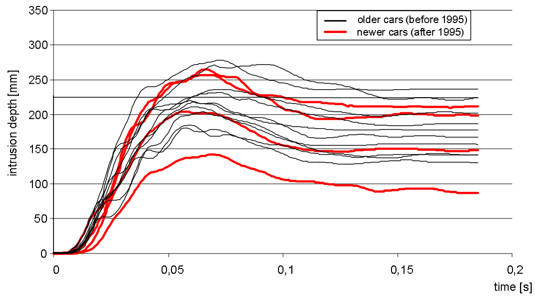


Figure 10. Rear door intrusion depth in side impact tests according to ECE R95.

Door Intrusion Velocity from ECE Tests

Regarding the intrusion velocity a comparable result can be observed. The intrusion velocity is again lower at the rear door compared with the front door.

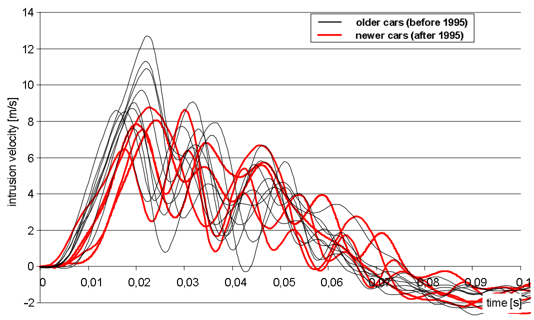


Figure 11. Front door intrusion velocity in tests according to ECE R 95 [Johannsen, 2005].

The intrusion velocity at the front door shows a range between 8 and 13 m/s (Figure 11), while the intrusion velocity at the rear door varies between 7 and 13 m/s (Figure 12).

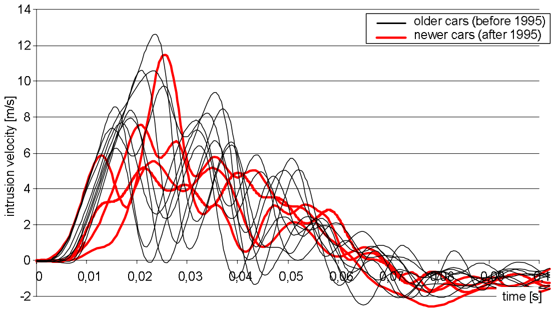


Figure 12. Rear door intrusion velocity in side impact tests according to ECE R95.

Taking into account the difficulties in positioning of the intrusion measurement device especially in smaller cars, a mean difference in intrusion velocity between front and rear door of 10% can be observed (Figure 13). The difference could be caused either by vehicle design or the test procedure with the centre of impact located more in the front.

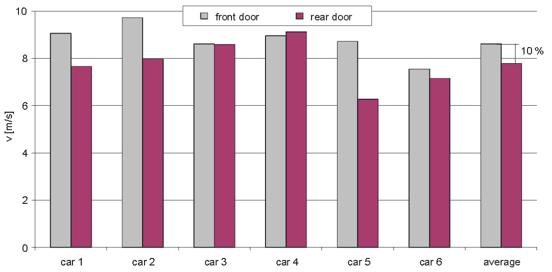


Figure 13. Comparison of maximum intrusion velocity for front and rear seat.

Door Intrusion Velocity in Car-to-Car Tests

For the development and assessment of a new European side impact test procedure several car-to-car and MDB-to-car side impact tests were conducted on behalf of EEVC/WG13 [Ellway, 2005]. These data help to analyse real-world side impact accidents, as passenger cars were used as the striking vehicles.
The intrusion measurement data presented below are acquired by acceleration based measurements for the Camry tests (except the AEMDB V2 test) and the Corolla car-to-car tests. For the other tests string potentiometers were used. The intrusion was measured close to the position of the thoraxes of driver and rear seat passenger but without interferences. When comparing acceleration based and string potentiometer based intrusion measurements, Ellway came to the conclusion that the first one tends to deliver higher residual velocity towards the end of the impact.
Figure 14 shows front door intrusion velocity of the inner door panel of an Alfa Romeo 147 running at 24 km/h which was struck by a Toyota Corolla travelling at 48 km/h. In a second test an Alfa Romeo 147 was struck by a Land Rover Freelander. While intrusion velocity in the Toyota test was approximately 6.5 m/s, the Land Rover Freelander caused an intrusion velocity of more than 12 m/s.

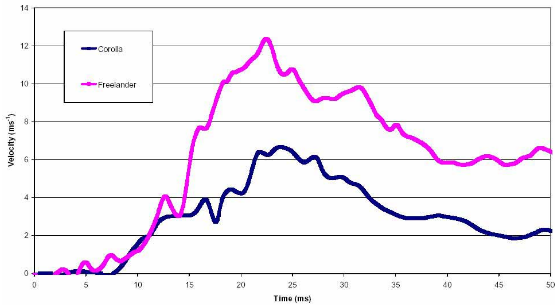


Figure 14. Comparison of front door intrusion velocity in car-to-car and SUV-to-car test [Ellway, 2005].

Looking at the rear door intrusion velocity of the inner panel these recorded approximately 7.5 m/s in the Corolla test compared to 10.5 m/s in the Land Rover Freelander test, see Figure 15.

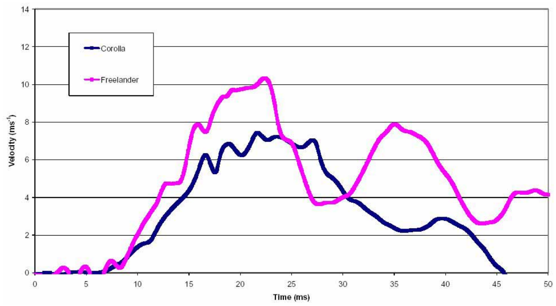


Figure 15. Comparison of rear door intrusion velocity in car-to-car and SUV-to-car test [Ellway, 2005].

Tests with a Toyota Camry, an executive saloon, showed again considerable differences between car-to-car (in this case a Ford Mondeo was used) and SUV-to-car tests. The intrusion velocities at the front door were approximately 5 m/s for the Mondeo and 9.5 m/s for the Freelander respectively, see Figure 16. For the rear door the intrusion velocities varied between 7 m/s (in the Ford test) and 10.5 m/s (in the Land Rover test, see Figure 17).

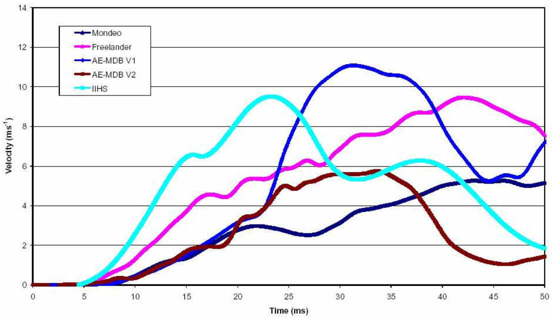


Figure 16. Comparison of front door intrusion velocity in different side impact tests with a Toyota Camry [Ellway, 2005].

The MDB tests were carried out utilising a barrier face stiffness and geometry (increased ground clearance) different from that of ECE R95. In addition the sled mass was increased to 1,500 kg. These measures should help to represent a more realistic accident severity.

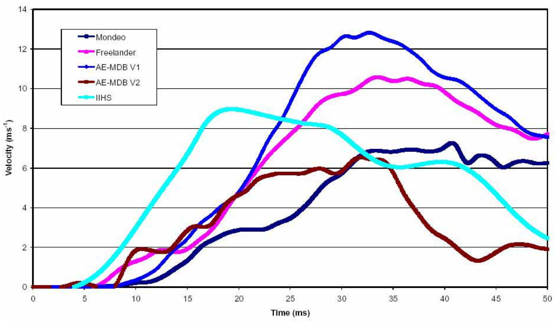


Figure 17. Comparison of rear door intrusion velocity in different side impact tests with a Toyota Camry [Ellway, 2005].

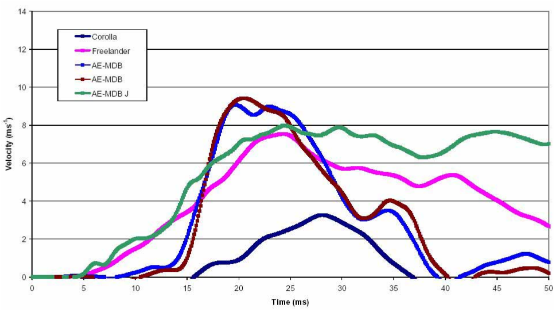


Figure 18. Comparison of front door intrusion velocity in different side impact tests with a Toyota Corolla [Ellway, 2005].

In the tests with a Toyota Corolla considerable differences between front and rear door are visible, see Figure 18 and Figure 19. While the intrusion velocity in the Corolla-to-Corolla test were relatively low for the front seat (approx. 3.5 m/s compared with 6 m/s at the rear door) this was contrary to the situation for all other tests.

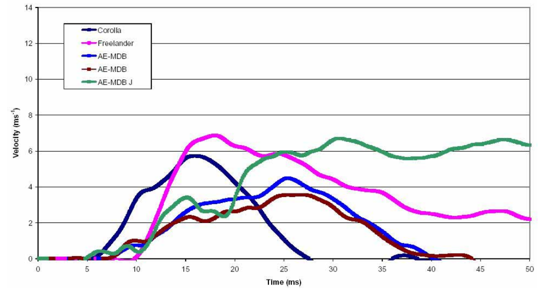


Figure 19. Comparison of rear door intrusion velocity in different side impact tests with a Toyota Corolla [Ellway, 2005].

Struck Car Acceleration and Velocity Change

In addition to the intrusion of the side structure the struck car experiences a lateral acceleration.

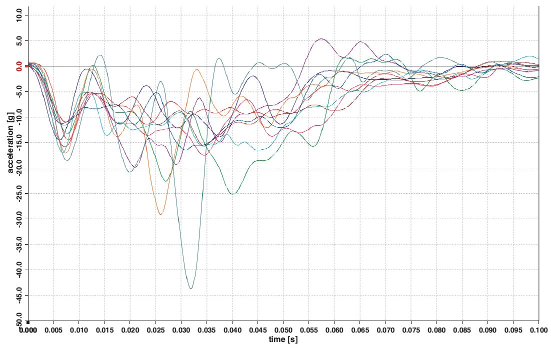


Figure 20. Acceleration of the struck car in ECE R95 tests [Nett, 2003].

Taking into account the theoretical velocity change for cars of an average weight in ECE R95 tests the struck car will be accelerated up to 22 km/h (Figure 20), which is in line with the derived velocity change from the vehicle acceleration time histories shown in Figure 21.

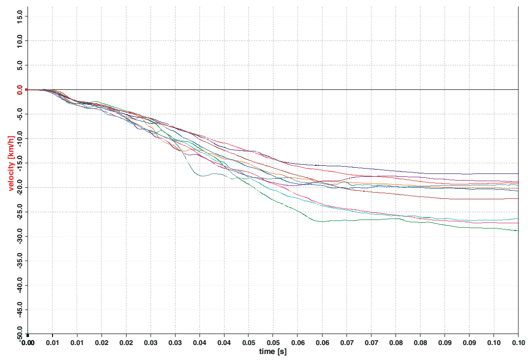


Figure 21. Velocity change of the struck car in ECE R95 tests [Nett, 2003].

Deformation Profiles

The comparison of static deformation of the struck vehicle from front to rear shows at first an increa-sing crush over a distance of about 500 mm, then a more or less constant crush over a distance of about 900 mm and then a decreasing trend (Figure 22).

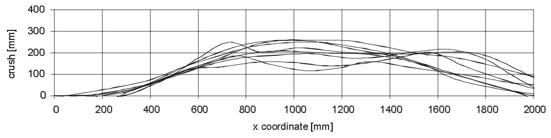


Figure 22. Static crush of different cars in ECE R95 tests [Johannsen, 2005].

The static crush in the EEVC/WG13 tests as described above show a comparable static crush as mentioned above, see Figure 24 and Figure 26. The crush distribution across the vehicle height shows significant differences; see Figure 23 and Figure 25. Again the influence of properties of the striking vehicle can be observed.

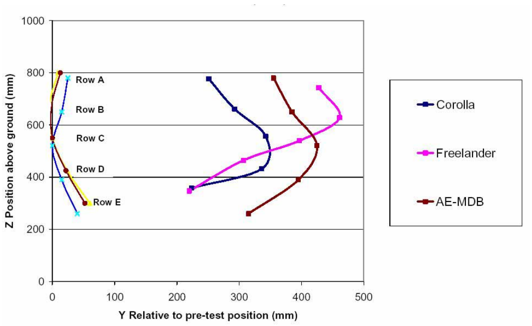


Figure 23. Static crush of Alfa 147 in several side impact tests (in Z-direction) [Ellway, 2005].

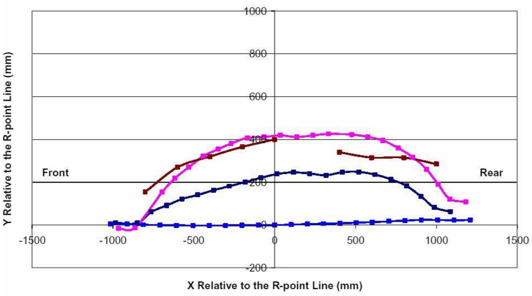


Figure 24. Static crush of Alfa 147 in several side impact tests (in X-direction row A) [Ellway, 2005].

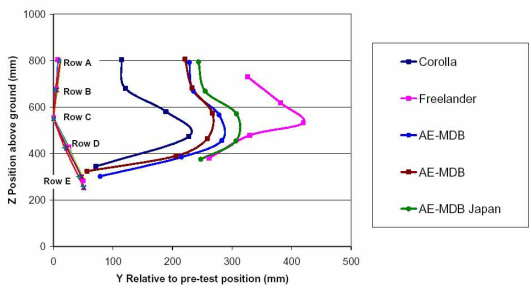


Figure 25. Static crush of Toyota Corolla in several side impact tests (in Z-direction) [Ellway, 2005].

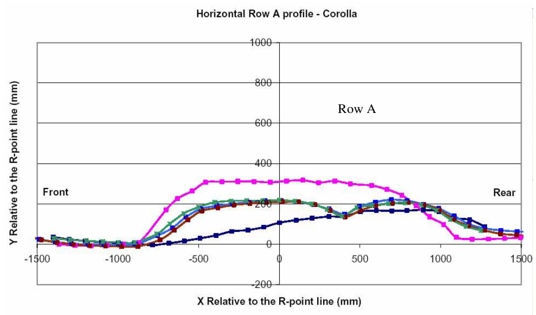


Figure 26. Static crush of Toyota Corolla in several side impact tests (in X-direction row A) [Ellway, 2005].

Dynamic Force-Deflection Characteristics of Door Interior

In addition to the dynamic behaviour, the geometric boundary condition of passenger cars, such as the lateral distance between seat and side structure, the height of the window sill in relation to the CR-point, and the stiffness of the side structure, are important.

The stiffness of the door trim, analysed in pendulum tests, showed considerable differences for different car models and different impact locations, see Figure 27.

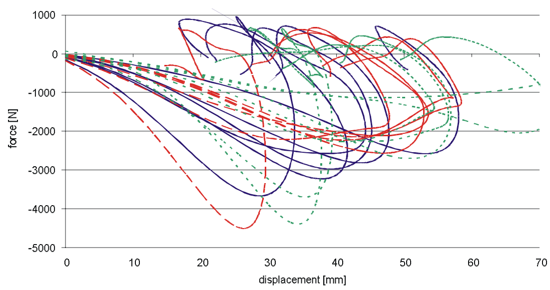


Figure 27. Door trim force-deflection of different locations at different doors [Nett, 2003].

Door window sill height and distance to door trim

Investigation of Nett [Nett, 2003] showed a lateral distance of the CRS centreline to the side structure of 300 mm and a window sill height of 500 mm. The average window sill height with respect to the CR point is approximately 500 mm, Figure 28.

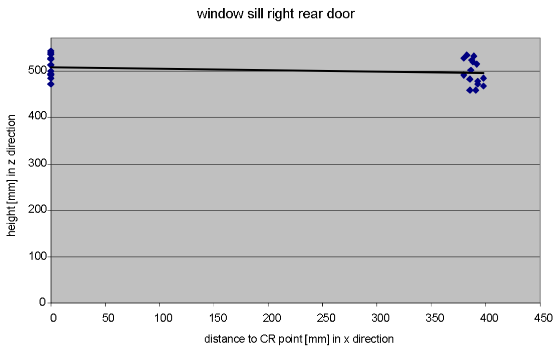


Figure 28. Height of the window sill in different cars [Nett, 2003].

The CRS centreline has an average distance to the inner door trim of approximately 300 mm [Nett, 2003], Figure 29.

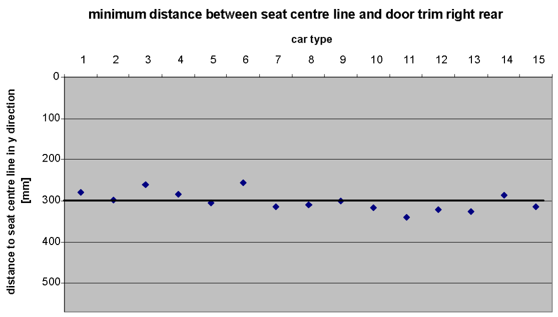


Figure 29. Lateral distance between CRS centreline and inner door trim [Nett, 2003].

REQUIREMENTS FOR THE SIDE IMPACT TEST PROCEDURE

The requirements of the ISO side impact test procedure for child restraint systems can be divided into the sections; test severity, validation, and field of application.

Test Severity

The test severity is defined by sled acceleration, intrusion depth and intrusion velocity (as far as intrusion is simulated), but also by geometrical measurements such as the panel height, distance of the CRS to the panel etc.
Analysis of full-scale side impact tests shows that the performance of current cars has been significantly improved during the last years. However, there are still old cars on the road and the test severity of the full-scale test is subject to several discussions as it is felt to be too moderate. One example for higher severity tests is the IIHS test procedure, where the mass of the barrier as well as the stiffness and shape of the barrier face, causes a more aggressive contact with the car in comparison to ECE R95 and FMVSS 214 test conditions.

Whilst there are no validated biomechanical load limits for children in side impact tests, the dummy readings resulting from the side impact test procedure should correlate with those measured in full-scale side impact tests.
Summing up the results presented in the section "Child Related Properties of Car Side Impact Test Methods" and the statements above, the following properties defining the test severity apply to a majority of cars in use:

- Intrusion velocity range: 7 – 10 m/s
- Intrusion depth: approx. 250 mm
- Sled acceleration range: 10 – 15 g
- Door panel height: approx. 500 mm
- Distance between door and CRS centre line: approx. 300 mm

In addition the padding specification needs to be fully defined.

Validation

For the validation of the test procedure, the test severity as well as the CRS definition according to the scope (see below) needs to be approved. Concerning the test severity, accident statistics show that the most important body region to protect is the head. Therefore it is necessary to put special emphasis on the validation of head loads and the capability of child restraints to contain the head inside the CRS during the test.

Field of Application

Besides the differences of forward facing and rear-facing the fixation of the CRS and the child can be different. The following types can be found in today's world markets: belt fixed CRS with integral harness for the child (FF mainly 5-point-harness, RF mainly 3-point-harness), booster with/without backrest (CRS and child restrained with car belt), ISOFIX connection of CRS and car with integral harness for the child. For the belted CRS the usage of tensioning devices, which reduce the belt slack of the car belt, are becoming more popular. The side impact test procedure has to be able to cope with all these different CRS types. In addition it is important that all these seats are tested with comparably realistic severity.

HISTORICAL OVERVIEW

Based on a side impact test procedure developed by TUB (Technical University of Berlin) within the EC funded project Brite ATASED (Advanced Technologies for Automotive Seat Evaluation and Design) TUB started testing CRS in lateral impacts. These tests were conducted in a double-sled arrangement, where the first sled impacted the second one. This double sled approach represents the deceleration and intrusion as recognised in car side impact tests. In the beginning a real car door was mounted on the striking sled, which impacted a CRS mounted on a car seat (see Figure 30).

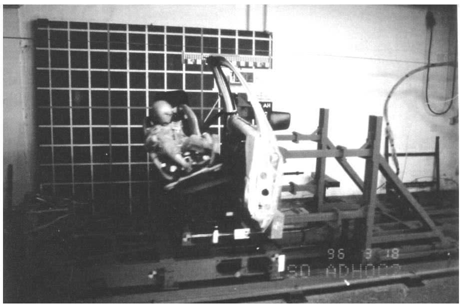


Figure 30. Double sled test set-up with car door and car seat.

In a later evolution a flat panel was used to represent the door and the CRS was mounted at an ECE R44 test bench. See Figure 31.

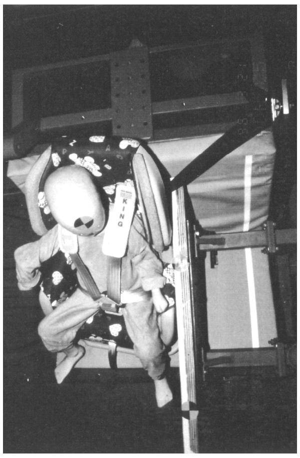


Figure 31. Double sled test set-up with flat panel and ECE R44 test bench.

It was then proposed by TRL (Transport Research Laboratory) to represent the intrusion with a hinged door. The hinged door was impacted by a 100 kg pendulum mass. Because of the relatively low mass the intrusion depth and intrusion velocity could not be reproduced in a satisfactory manner. Both depended on the CRS fixture, CRS weight etc. However, the principle idea of the hinged door concept seemed to be a good compromise of reproducing vehicle acceleration and intrusion.
To reduce the complexity of the hinged door procedure, the Nordic European countries proposed to use a curved panel as a door, which is fixed at the concrete block. The intrusion velocity in this approach is defined by the initial sled velocity. As the intrusion velocity in lateral impacts is higher than the lateral velocity change of the struck car, the Nordic countries proposed to use a suitable intrusion velocity as initial sled speed. The sled was then decelerated during the contact with CRS and dummy to meet the intrusion depths requirement. This procedure was realised by TNO with a flat panel.
Another proposal, coming from MPA Stuttgart, was to impact the CRS by a panel without reproducing the vehicle movements.

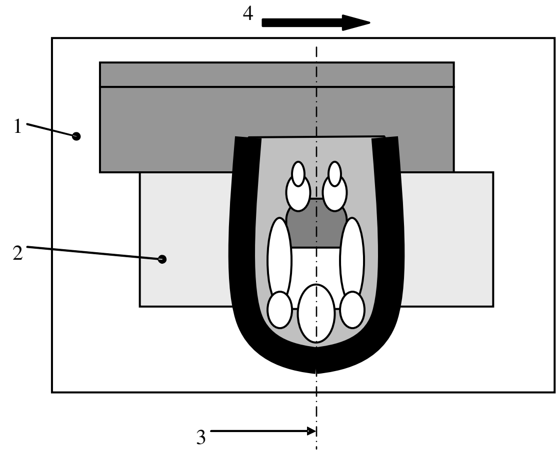
CURRENT SIDE IMPACT TEST PROCEDURES FOR CHILD RESTRAINT SYSTEMS

This clause gives a brief summary of the existing side impact test procedures for child restraint systems.

ISO/DIS 14646 / TRL Test Procedure

The child restraint working group of ISO (ISO/TC22/SC12/WG1) started in 1994 the development of a side impact test procedure for child restraint systems. Most of the procedures described in previous section were proposed and discussed within the responsible task group. Finally in the end of the nineties the decision was taken to use a derivative of the hinged door concept as proposed by TRL.
The main problem recognised with the original hinged door concept was the considerable influence of the CRS on intrusion velocity and intrusion depth. This was mainly caused by the relatively low impactor mass. Finally the activating method of the intruding panel was not defined in the protocol but corridors for intrusion velocity and an intrusion depth was fixed.
Due to the proposed hinged door method it is important to define the worst-case conditions. The contact velocity between the CRS (child dummy, respectively) and the intruding panel depends on the angular velocity of the panel and the distance of the CRS (defined by the position of the head) to the hinge line. In order to test rear-facing and forward facing CRS with the same test severity, it is necessary to use different hinge line positions with respect to the CR point. Within ISO it was decided to test in worst-case conditions, which means with the maximum intrusion close to the dummy's head, requiring the hinge line far from the dummy's head.
The draft standard was subject to two subsequent DIS votes. After failing the first one, it was decided to improve the draft standard for rear-facing CRS, while defining the details for forward facing CRS in a second part. For the second vote only the part covering RF CRS was presented, the second part should be published as a Technical Report. However the standard proposal was disapproved also during the second DIS vote (by a small margin).

Description of the ISO Test Method - The main property of the ISO 14646 test procedure is the hinged door concept where an ECE R44 test bench is mounted at an angle of 90° on a sled. To avoid interactions between the intruding panel and the test bench backrest, the latter one is displaced by 100 mm, see Figure 32.

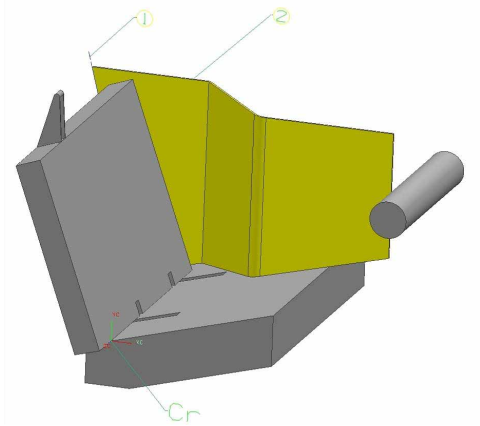


Key

1 Sled
2 ECE R.44 test bench
3 CRS centreline
4 Travel direction

Figure 32. General test setup in ISO/DIS 14646.

The hinge line of the intruding panel is perpendicular to the seat cushion by means of an angle of 15° to the ground. The simulated intrusion should realise an intrusion depth of 250 mm and a maximum intrusion velocity of 9 m/s.
The panel shape was subject to several discussions within the responsible task group. After initially testing with a flat panel, curved and shaped panels were developed and tested. The main advantage of a shaped panel is the fact that it is possible to define a maximum intrusion, which is not the case with a flat panel. Finally a double shaped panel according to Figure 33 was developed.
During the sled deceleration the hinged door intrudes. The CRS is positioned with a distance of 300 mm of its centreline from the hinged door. The test procedure takes into account the worst-case scenario for both, RF and FF CRS, by positioning the hinge at the side of the feet of the child dummy. The sled deceleration is defined by a delta-v corridor representing an overall delta-v of 25 km/h. The hinged door concept transfers the translational into a rotational intrusion. The middle angular velocity for RF CRS of 13 rad/s corresponds to a translational intrusion velocity at the point of the head of about 12 m/s.
The test procedure according to ISO/DIS 14646 was implemented at TRL.



Key

1 Panel hinge line
2 Hinged panel

Figure 33. Seat bench construction with panel for RF configuration of ISO/DIS 14646.

Voting Results - The draft ISO standard was disapproved in both DIS votes. Numerous comments were provided for both votes.
In the first vote ISO/DIS 14646 was disapproved by five countries (France, Italy, Japan, Netherlands, US). The main reason for the disapproval was the missing validation, especially for the test set up for FF CRS.
During the second vote, again five countries disapproved the proposal. This time France, Germany, Japan, Philippines and Sweden voted against the draft especially because of separate parts describing the test methods for FF and RF seats, and again the missing validation, especially regarding reproducibility.

TNO Test Procedure

The TNO procedure is based on an earlier stage of the ISO 14646. The main difference to ISO is the utilisation of a flat panel and a different padding. In principle the TNO procedure was intended to be used for both, RF and FF CRS, in worst-case conditions, but the set up for FF worst-case has not been realised yet.

TUB Test Procedure

The test procedure developed by the Technical University Berlin is again based on the hinged door concept. TUB started the development in 1999 based on the resolutions and decisions taken by ISO WG1.
The main differences with respect to ISO 14646 are different hinge line orientation, different panel shape and different panel padding. In addition the backrest and upper belt anchorage point in FF configuration are both moveable in the Y direction and firmly connected with the intruding panel representing the seat and B-pillar displacement in

full-scale crash tests. The lower ISOFIX anchorages are free to move in Y-direction.
The hinge line in the TUB method is vertical to the ground allowing the same hinge to be used for both test set-ups. The single shaped panel is padded with a thicker and softer material compared to the ISO procedure.
The TUB test procedure was selected to be used for the NPACS Programme (New Programme for the Assessment of Child Restraint Systems) at the end of 2005.

ADAC Test Procedure

The ADAC (Germany Motoring Club) tests take place in a body-in-white of a VW Golf [Gauss, 2002]. The body-in-white is mounted on a sled at an angle of 80° and is equipped with a fixed door. The angle of 80° should cause an additional head movement in frontal direction. Therefore it is more difficult to pass the head containment criterion for FF CRS. The body in white is mounted in the same way to the sled for FF and RF CRS. In the ADAC procedure a fixed door is used, i.e. no intrusion is simulated. The sled is decelerated from an initial velocity of 25 km/h at a level of 15 g. The main advantage of this test procedure is that it is considerably simpler, enabling good performance with respect to reproducibility.

Australian Standard AS/NZS 1754 Test Procedure

In Australia and New Zealand two different kinds of side impact tests for homologation of child seats have to be used. One test is on a test bench, which is mounted at 90° on a sled, without any door and the second test is with a fixed door, again at 90° angle. The first test assesses for dummy ejection in lateral impacts and has been in the standards for over 20 years while the latter test assesses the head containment capabilities of the CRS. For the door-less tests, selected TNO P series dummies are used for forward facing seats and boosters, while a TARU Theresa dummy is used for infant restraints. Selected TNO P series dummies are used for the tests in which the door is utilised. The sled is calibrated to undergo a velocity change of not less than 32 km/h, with a deceleration of 14 – 20 g. The door used was based on research work from the Child Restraint Evaluation Program with changes to construction of the angle on the top half of the door. This side impact testing with the door was introduced in to the 2004 version of the standard.

Australian CREP Test Procedure

The consumer information testing in Australia is known as the Child Restraint Evaluation Program (CREP). There have been three rounds conducted and published. There are two side impact tests, one at 90° and the other at 66° (previously 45°), both with a fixed door structure in place. The test conditions are the same as AS/NZS 1754 (see above), however there are additional assessment criteria. Selected TNO P Series dummies are used for testing. In some instances they are modified to increase their seated height.

CURRENT STATUS AND FUTURE RESEARCH FOR ISO 29062

The restarted project has been accepted as a new work item proposal as ISO 29062.According to the ISO rules the standard must be published before November 2009.
The current focus of the subgroup developing the final standard is the definition of appropriate corridors addressing repeatability and reproducibility as well as the validation of the test procedure taking into account the application of the procedure, the test severity etc.

Corridor Specification

The current corridors for sled delta-v and the angular velocity are shown in Figures 34 and 35

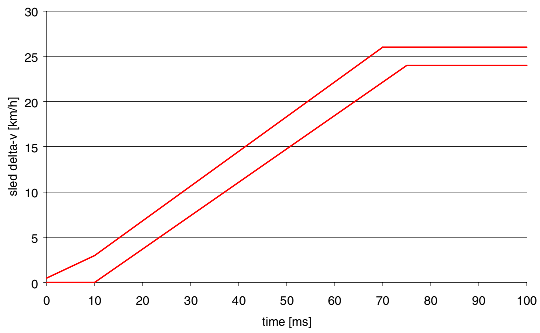


Figure 34. Sled delta-v corridor.

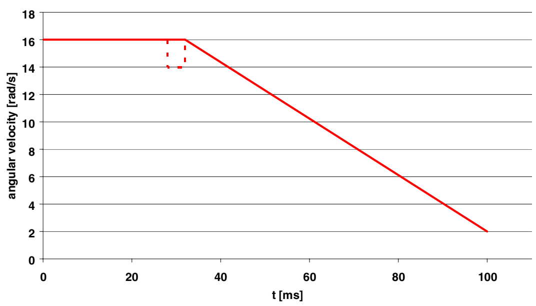


Figure 35. Angular velocity corridor for FF CRS.

The combination of both corridors was felt to offer too much variety. For analysing the effect of the allowed tolerance numerical simulations utilising MADYMO with a generic FF CRS were performed (see Figure 36).

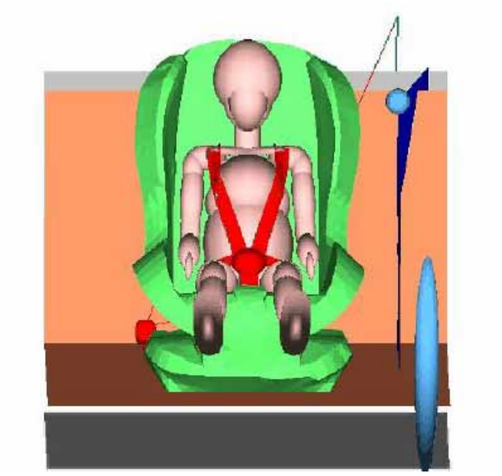


Figure 36. Set-up for the analysis of the corridors [Rooij, 2005].

The contact velocity between panel and CRS was used as an indicator for the dummy readings as the used CRS model did not allow reliable assessment of the dummy readings.

These simulations show that the procedure is sensitive to the timing of the door angular velocity while the maximum value of the door velocity and the sled pulse show only a minor influence on the test results, see Figures 36 and 37.

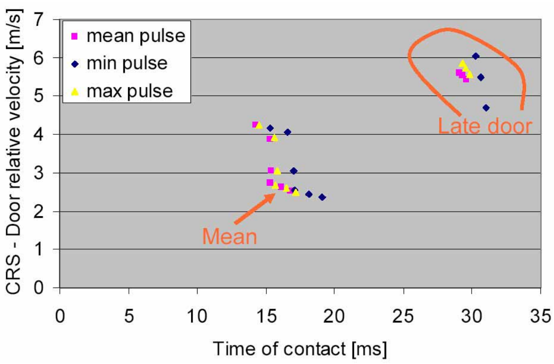


Figure 37. Influence of door timing and sled pulse on the contact velocity.

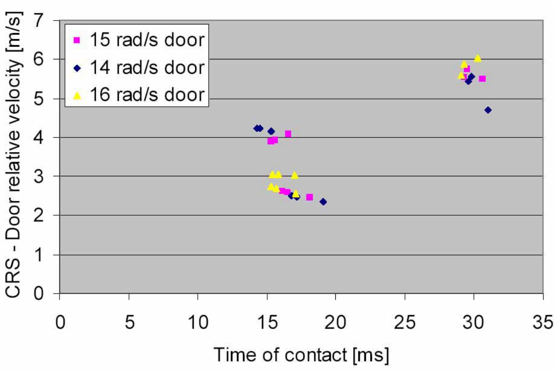


Figure 38. Influence of door timing and panel speed on the contact velocity.

The future revised corridors should address the timing issue recognised above but has to be feasible.

Test Severity

The test severity of the current drafted standard is mainly based on cars of the eighties and nineties. Due to considerable changes in new cars adoption of the test severity might be necessary.
Intrusion velocity and door panel height are the main parameters currently under discussion. For styling reasons the window sill height, especially at the rear seat, changed considerably during the last years. An increased door panel height results in higher dummy readings but reduces the challenges concerning the head containment for high-back booster seats.
The data presented above show a considerably lower intrusion velocity for newer cars compared with older ones. This behaviour is caused by improved vehicle design. For defining a sustainable test procedure it is necessary to keep this development in mind.

Forward Component

The US side impact test procedures for cars (FMVSS 214 and US-NCAP) as well as the ADAC side impact test procedure for CRS represent a forward component of the sample car. The drafted standard describes a purely lateral impact. Currently advantages and disadvantages of including a forward component are investigated. European accident statistics indicate that perpendicular and angled side impact accident happen with an equal share while the purely lateral ones seem to be more severe.
The next steps are to include US accident data, to analyse the velocity change in US-NCAP tests and to assess the influence of including a forward component to the dummy readings.

CONCLUSIONS

Accident statistics prove that side impact accidents are dangerous for children travelling at the struck side in passenger cars. Although the number of seriously injured children has decreased during the last decades, there is still a considerable risk especially for head, neck and thorax injuries.
Comparing RF and FF CRS there are indications in the accident statistics that rear facing seats protect children better in side impact than forward facing child restraint.
Side impact test procedures for cars, which are designed to represent average accident conditions, are mainly MDB tests with a barrier travelling either perpendicular to the struck car or at a crabbed angle. In addition to the direction

differences in barrier weight, speed, geometry and stiffness exists. The most severe test procedure seems to be the IIHS side impact test procedure simulating an SUV striking the test car.
When analysing test results of ECE R95 side impact tests it becomes evident that injures are caused by the combination of both structural intrusion and vehicle acceleration. The intrusion is defined by intrusion shape, intrusion depth and intrusion velocity. In addition geometrical properties (such as door panel height, distance between side structure and CRS etc.) of the struck car have a considerable influence. An appropriate side impact test procedure for CRS should be capable to reproduce the following properties:

- Intrusion velocity range: 7 – 10 m/s
- Intrusion depth: approx. 250 mm
- Sled acceleration range: 10 – 15 g
- Door panel height: approx. 500 mm
- Distance between door and CRS centre line: approx. 300 mm

In addition the padding specification needs to be fully defined.
In addition the test procedure should be repeatable and reproducible and should offer the possibility to test all kinds of CRS at a comparable severity level. The proposed side impact test method for CRS according to ISO DIS 14646 reproduces vehicle acceleration by a sled and intrusion by a hinged panel. It has been disapproved in two votes; mostly because concerns that additional validation of the procedure would have been necessary.
As a consequence of the disapprovals of the proposed ISO procedure, and taking into account the alternative method development, ISO/TC22/SC12/WG1 adopted the following resolution in November 2005:
"Considering the disapproval of DIS 14646-1.2, and the recent information that NPACS have just decided to use a method similar to the TUB method for side impact CRS rating, WG 1 decided to change direction of the ISO work in recognition of the NPACS decision." *(Excerpt of resolution 180, adopted at the 34th meeting in Arlington (USA), 2005-11-17.)*

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